ME 321: Fluid Mechanics-I

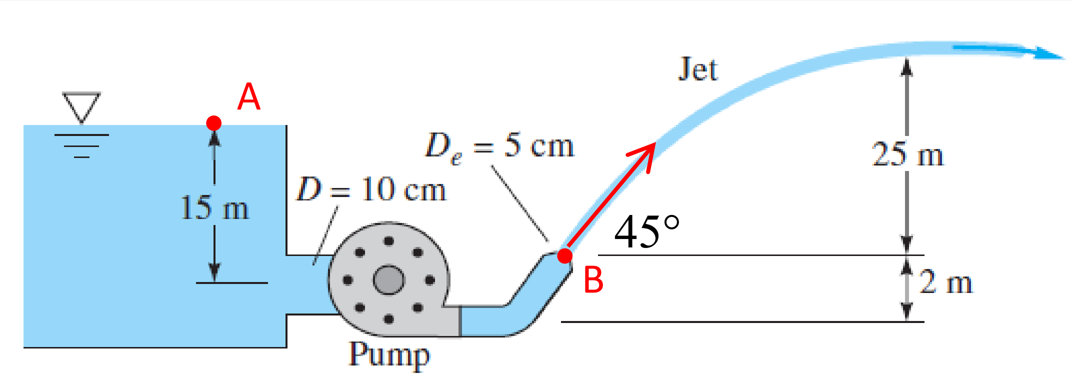
Prof. Dr. A.B.M. Toufique Hasan
Department of Mechanical Engineering
Bangladesh University of Engineering and Technology (BUET)

Lecture - 11 (12/07/2025)
Fluid Dynamics: Applications of Bernoulli Equation

toufiquehasan.buet.ac.bd
toufiquehasan@me.buet.ac.bd

Problem 13

The pump in the figure creates a water jet oriented at 45°. System friction head losses are 6.5 m. The jet may be approximated by the trajectory of frictionless particles. What power must be delivered by the pump?
How much electrical power is required to run this operation if pump efficiency is 65%?



Solution:

For vertical distance traveled by the jet is

$$V_f^2 = V_i^2 - 2gz$$

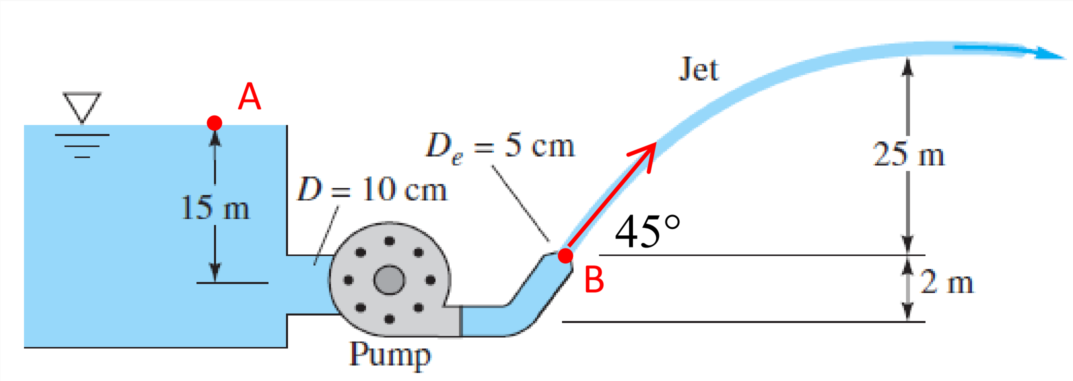
For **maximum vertical distance** traveled by the jet is

$$V_f = 0$$
$$V_i = V_B \sin 45°$$

$$\therefore V_B \sin 45° = \sqrt{2gZ_{\max}}$$

$$\therefore V_B = \frac{\sqrt{2gZ_{\max}}}{\sin 45°} = \frac{\sqrt{2(9.81)(25)}}{\sin 45°} \approx 31.3 \text{ m/s}$$

Problem 13



$$\frac{p_A}{\gamma} + \frac{V_A^{\,2}}{2g} + z_A + h_P = \frac{p_B}{\gamma} + \frac{V_B^{\,2}}{2g} + z_B + h_L$$

$$\Rightarrow 0 + 0 + 15 + h_P = 0 + \frac{31.3^2}{2g} + 2 + 6.5$$

$$\Rightarrow h_P = 43.4 \text{ m}$$

Power must be delivered by the pump $P_{Pump} = \gamma Q h_P = (1000)(9.81)\left(\frac{\pi}{4}(5\times10^{-2})^2(31.3)\right)(43.4)$

$$\Rightarrow P_{Pump} = 26.2 \text{ kW}$$

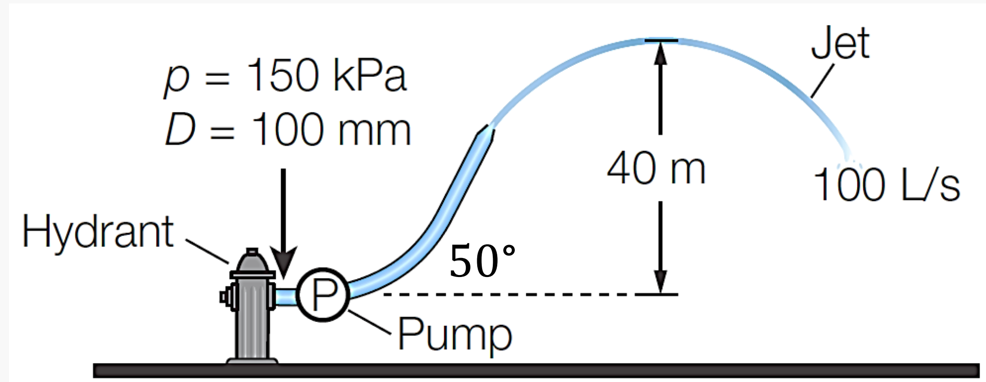
Electrical power required for this operation

$$\eta = \frac{P_{out}}{P_{in}} = \frac{\gamma Q h_P}{P_{in}\,(\text{elect. power})} \quad \Rightarrow 0.65 = \frac{26.2}{P_{in}}$$

$$\Rightarrow P_{in} = 40.3 \text{ kW} \qquad (\text{Ans.})$$

Problem 14

A pump is attached to a fire hydrant as shown in Figure, where it is desired to produce a jet that rises to a maximum height of 40 m and delivers water at a rate of 100 L/s. At the attachment location, the diameter is 100 mm and the pressure is estimated as 150 kPa. The discharge nozzle has a diameter of 80 mm and is inclined at an angle of 50° to the horizontal. If friction losses are neglected, estimate the head that must be added by the pump to achieve the desired objective. Approximately how much power will it take to run the pump?



Solution:

$$V_B = \frac{(100/1000)}{\frac{\pi}{4}0.08^2} = 19.9\ m/s \qquad V_A = 12.7\ m/s$$

For vertical distance traveled by the jet is

$$V_f^2 = V_i^2 - 2gz$$

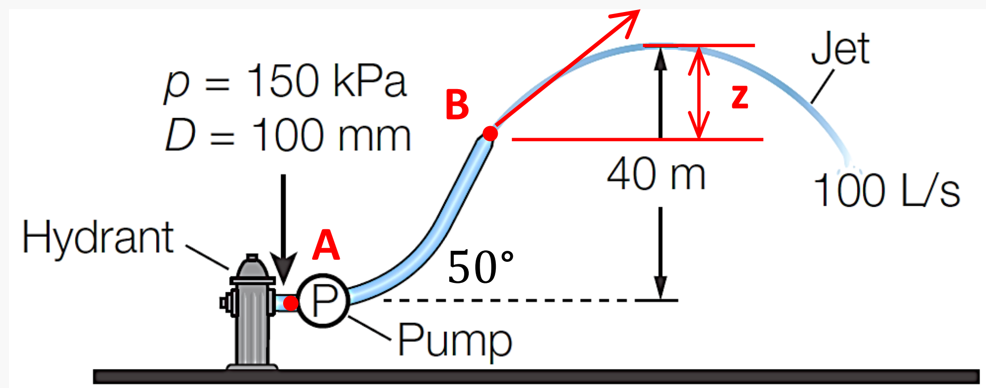
For **maximum vertical distance** traveled by the jet is

$$V_f = 0$$

$$V_i = V_B \sin 50°$$

$$0 = (19.9 \sin 50)^2 - 2(9.81)z$$

$$z = 11.8\ m$$

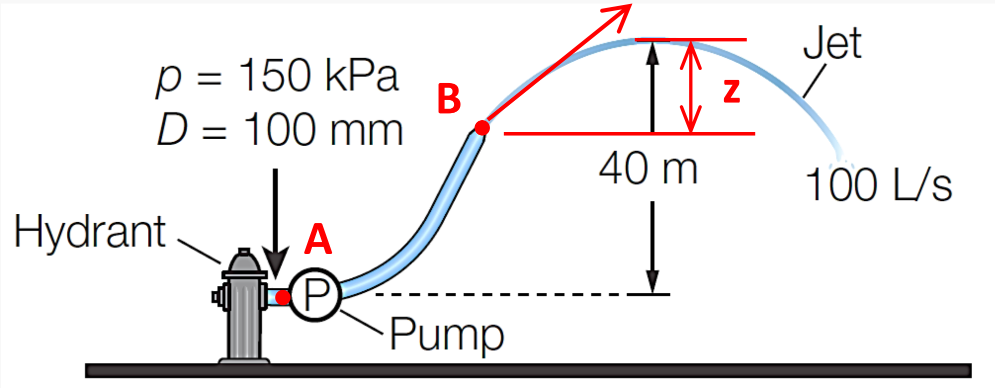


Problem 14

$$\frac{p_A}{\gamma} + \frac{{V_A}^2}{2g} + z_A + h_P = \frac{p_B}{\gamma} + \frac{{V_B}^2}{2g} + z_B$$

$$\Rightarrow \frac{150 \times 10^3}{9810} + \frac{12.7^2}{2g} + 0 + h_P = 0 + \frac{19.9^2}{2g} + (40 - 11.8)$$

$$\Rightarrow h_P = 24.9 \text{ m}$$



$$P_{Pump} = \gamma Q h_P = (1000)(9.81)(100/1000)(24.9)$$

$$\Rightarrow P_{Pump} = 24.4 \text{ kW}$$

Considering the pump efficiency of 70%

$$P_{Elect.} = 34.9 \text{ kW (Ans.)}$$

Problem 15

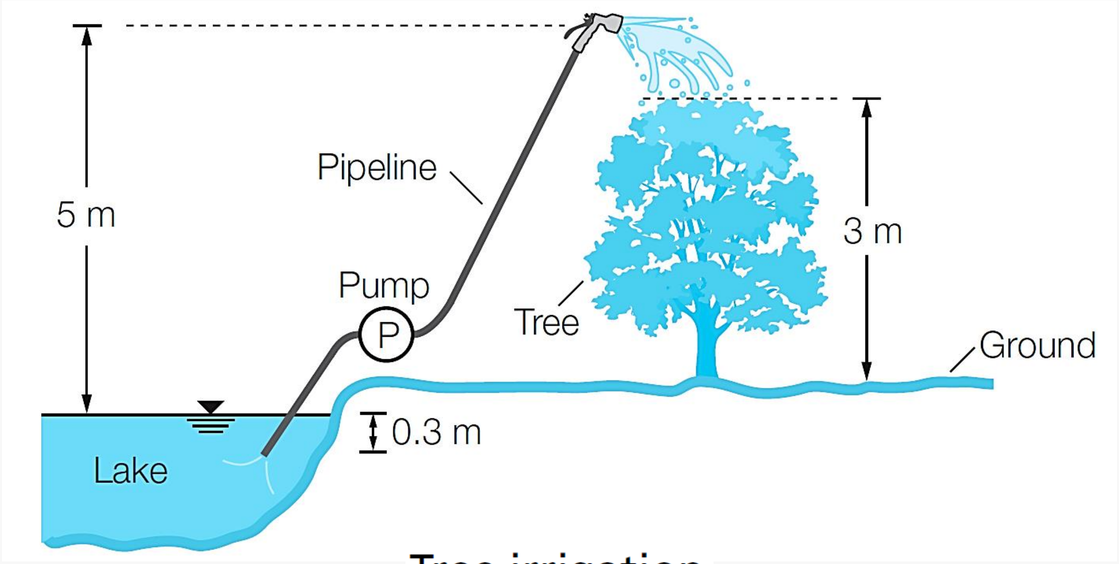
Water is to be pumped from a lake to irrigate a tree as shown in Figure. The head loss in the 50-cm-diameter pipeline, h_ℓ [m], is a function of the flow rate, Q [m^3/s], according to the relation

$$h_\ell = 1.05Q^2$$

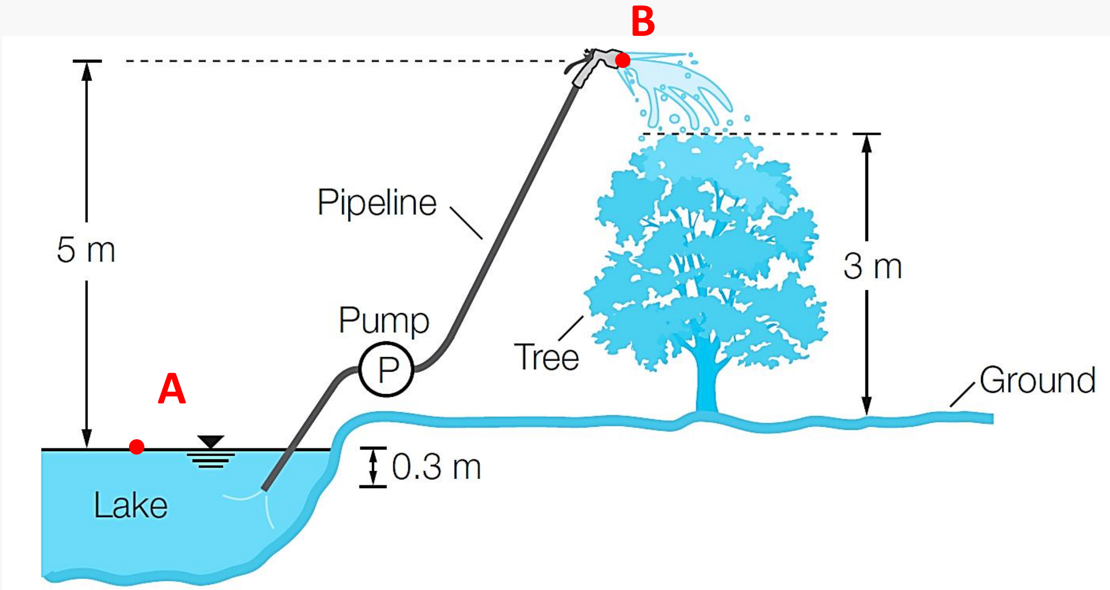
The desired flow rate is 1 m^3/s, and the pump efficiency is assumed to be 80%.

(a) What size pump would you select for the job?

(b) If a nozzle of diameter 25 cm is attached to the end of the pipeline, will the same size pump be adequate? If not, calculate the pump size that is required in this case.



Tree irrigation



Ans. (a) 90.4 kW
(b) 333.5 kW

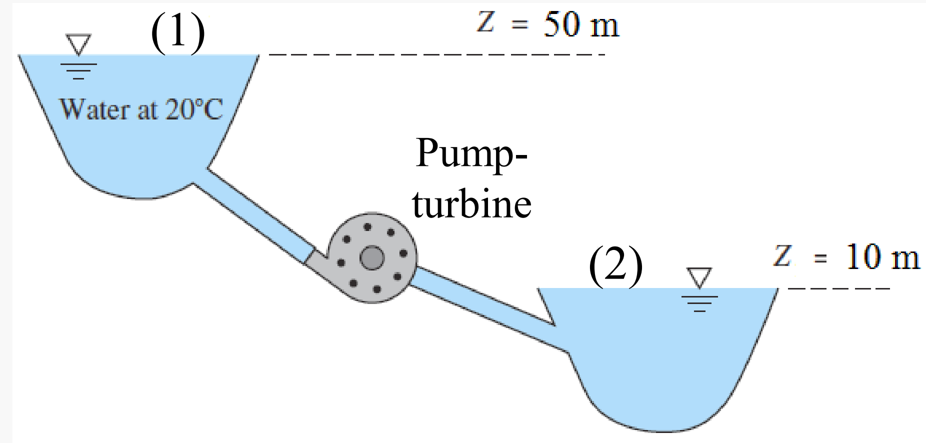
Problem 16

The *pump-turbine* system in the figure draws water from the upper reservoir in the daytime to produce power for a city. At night, it pumps water from lower to upper reservoir to restore the situation. For a design flow rate of 50,000 lit/min in either direction, the friction head loss is 5 m.

Estimate the power in kW

(a) extracted by the turbine and

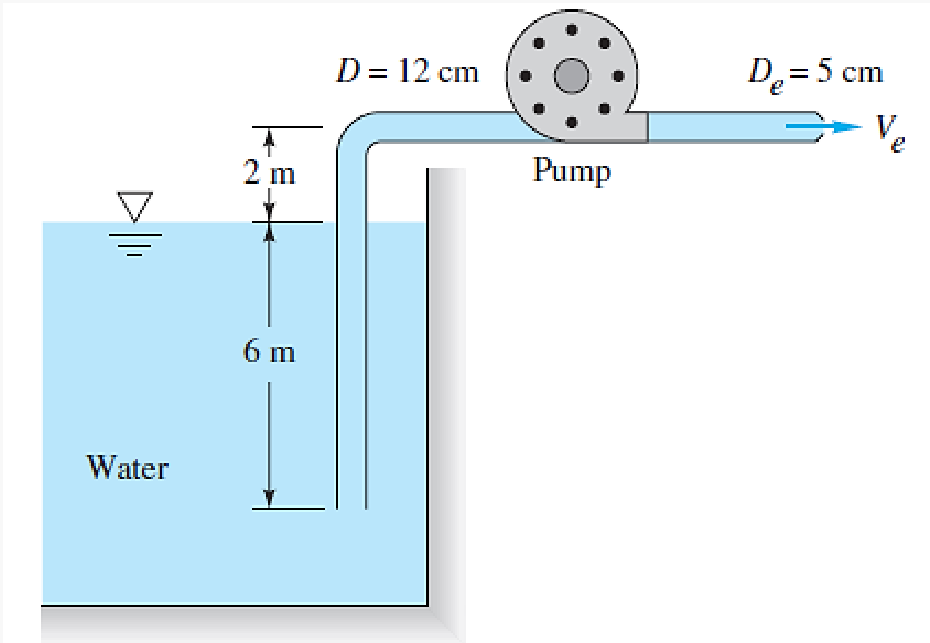
(b) delivered by the pump.



Solution:

Problem 17

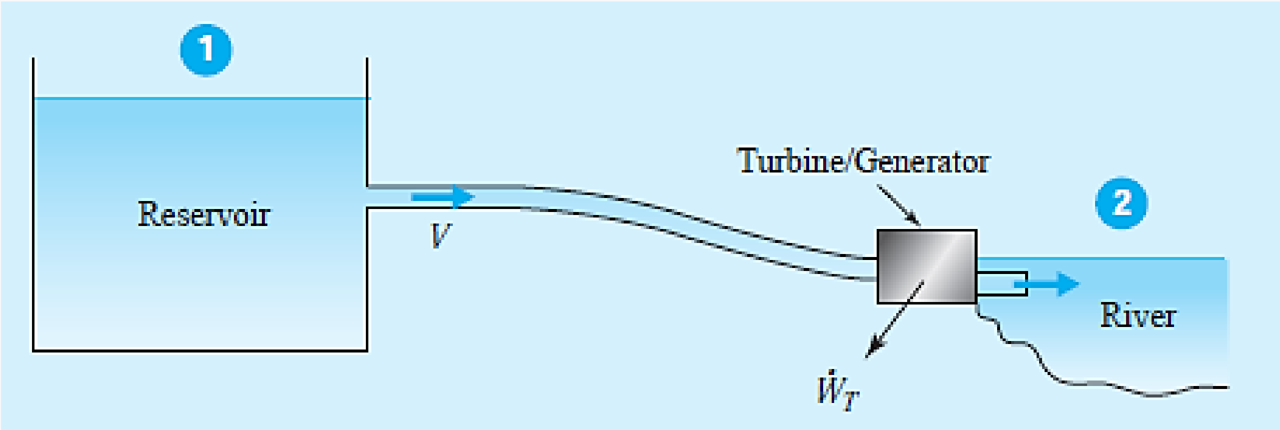
When the pump in Fig. draws 220 m^3/h of water at 20°C from the reservoir, the total friction head loss is 5 m. The flow discharges through a nozzle to the atmosphere. Estimate the pump power in kW delivered to the water.



Solution:

Problem 18

Water flows from a reservoir through a 0.76 m-diameter pipeline to a turbine-generator unit and exits to a river that is 35 m below the reservoir surface. If the flow rate is 9200 m^3/hr, and the turbine-generator efficiency is 88%, calculate the power output.
Assume the loss coefficient in the pipeline (including the exit) to be K = 2.



Flow Measurement

Pitot tube

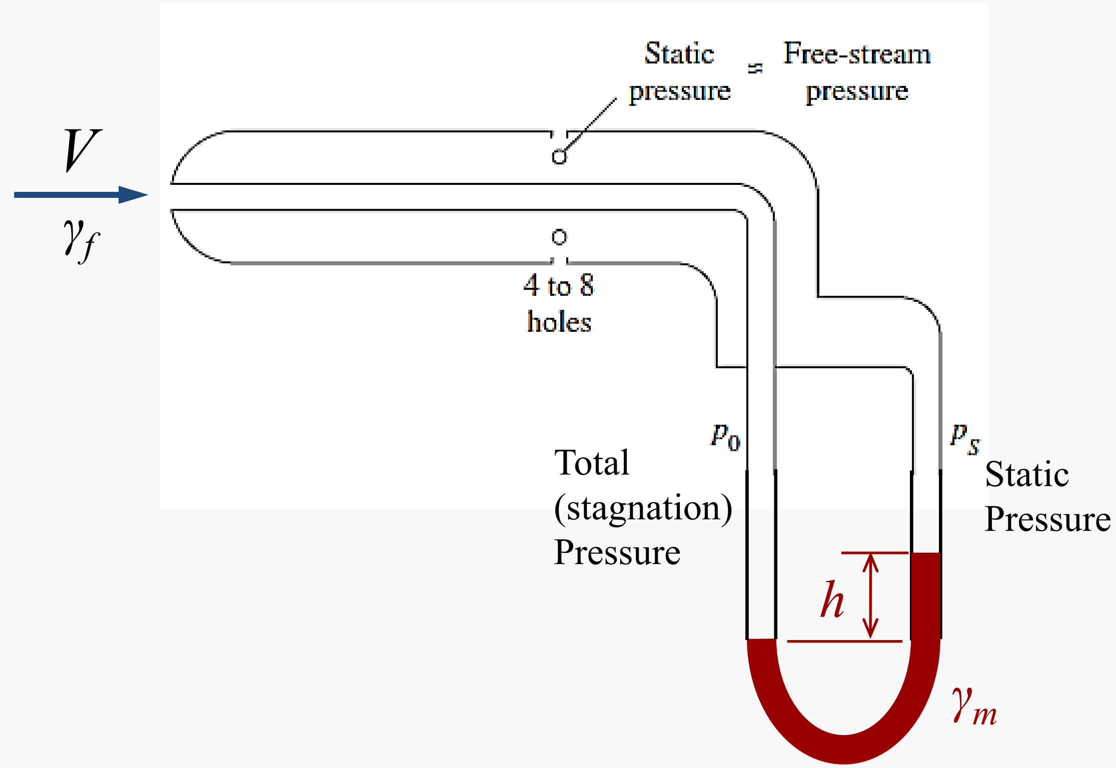
For local velocity measurement inside duct, wind tunnel etc.

Apply Bernoulli equation between stagnation point and static point:

$$\frac{p_0}{\gamma_f} + \frac{V_0^2}{2g} + z_0 = \frac{p_s}{\gamma_f} + \frac{V^2}{2g} + z_s$$

$$\Rightarrow \frac{p_0}{\gamma_f} = \frac{p_s}{\gamma_f} + \frac{V^2}{2g}$$

$$\Rightarrow V = \sqrt{\frac{2(p_0 - p_s)}{\rho_f}}$$



Pitot tube (pitot-static tube)

Pitot tube

Now from principle of manometry

$$p_0 + \gamma_f h_1 = p_s + \gamma_f (h_1 - h) + \gamma_m h$$

$$\Rightarrow p_0 = p_s - \gamma_f h + \gamma_m h$$

$$\Rightarrow p_0 - p_s = h(\gamma_m - \gamma_f)$$

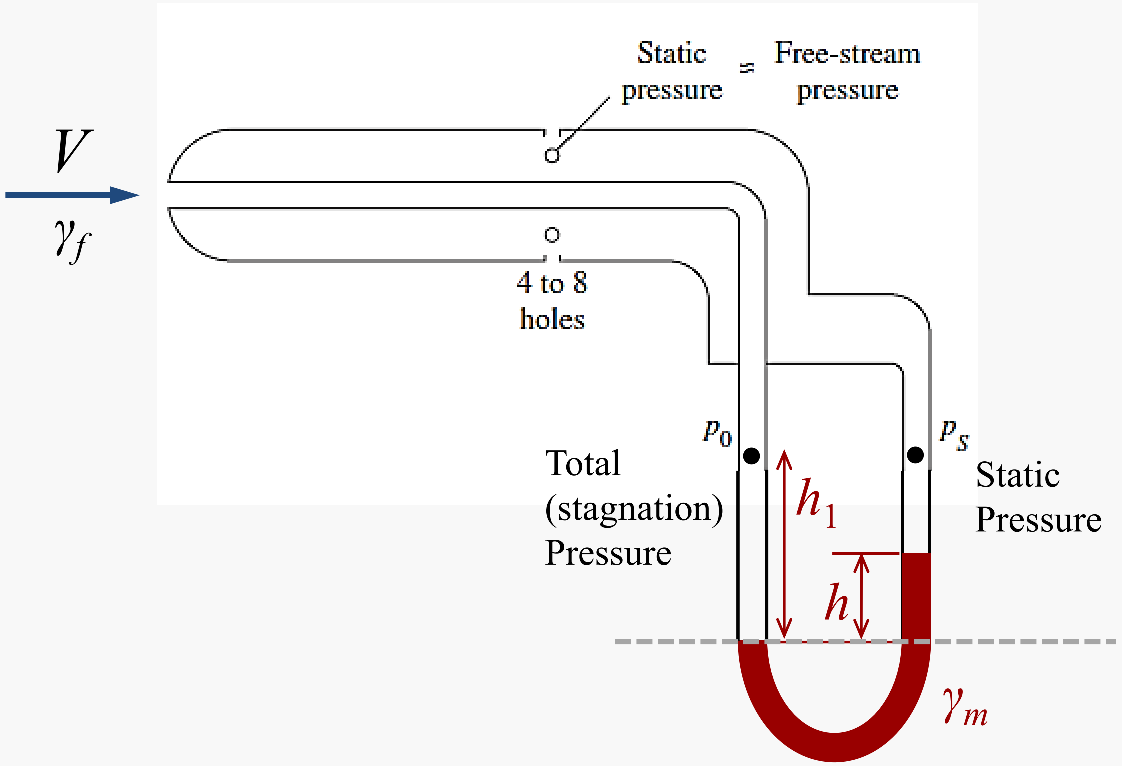
$$\Rightarrow p_0 - p_s = \gamma_f h \left(\frac{\gamma_m}{\gamma_f} - 1 \right)$$

$$\boxed{\Rightarrow p_0 - p_s = \gamma_f h \left(\frac{S_m}{S_f} - 1 \right)}$$

So, the velocity can be measured as follows:

$$\Rightarrow V = \sqrt{\frac{2(p_0 - p_s)}{\rho_f}}$$

$$\boxed{\Rightarrow V = \sqrt{2g \left(\frac{S_m}{S_f} - 1 \right) h}}$$



Pitot tube (pitot-static tube)

m: manometric fluid
f: flowing fluid

Problem

A tube is used to measure the total pressure inside a wind tunnel as shown in figure. If the water column height in the manometer h = 8 cm, calculate the velocity at the test section.

If the surface area of the car is 5 m^2 and measured drag force is 800 N, determine the drag coefficient at this condition.

Hint: $C_D = \dfrac{F_D}{\frac{1}{2}\rho V^2 A}$